## I. INTRODUCTION

The purpose of this report is to provide a technical critique of the ACTV system proposed by the David Sarnoff Research Center. The technical critique will be among the considerations before the Systems Subcommittee's Working Party 1 in deciding on final certification of the ACTV system prior to testing. The report may also be useful to Working Party 4 of the Systems Subcommittee in its deliberations leading to a final recommendation, and to Working Party 2 in defining system-specific tests. The focus in our analysis has been on issues particular to the ACTV system that we believe require special attention during the testing, including additional system-specific tests and observations beyond those set forth in the testing plans.

The report includes a brief description of the ACTV system, a summary of potential impairments, a section on compatibility with NTSC, and recommendations for system-specific tests and observations. There are four appendices covering an initial list of questions for Sarnoff from the Analysis Task Force, the response from Sarnoff to those questions, items for which further clarification is desired, and working documentation from the system proponent.

## II. SUMMARY DESCRIPTION OF ACTV SYSTEM

The following describes the main technical features of the ACTV system as understood by the Task Force. For diagrams and further details, refer to the system description provided by Sarnoff, attached as Appendix D.

The ACTV system is defined as an enhanced NTSC-compatible TV system, and it uses a single 6 MHz television transmission channel. Because it is claimed that the ACTV signal is compatible with NTSC, existing NTSC receivers that receive the ACTV signal must display an acceptable NTSC version of the transmitted scenes, while an ACTV receiver will display a wide-screen image with increased horizontal resolution and perceptually improved vertical resolution resulting from a display with 525-line progressive scanning.

The methods employed to achieve enhanced video performance while retaining NTSC compatibility start with pre-filtering of the 525 line progressively-scanned input video in the vertical and temporal dimensions and subsampling to produce an interlaced video signal that will result in minimum aliasing components after subsequent sampling and processing. The input video signal derives from a wide-screen image, having a 16:9 aspect ratio, but is represented in the same signal space (525 lines, 52 microseconds per active line) that is currently occupied by the standard NTSC signal. The central portion of this interlaced signal is time-expanded to almost the standard 4:3 aspect ratio (within about 5%) to yield an NTSC-compatible component. The low-frequency luminance information from the side panels (required to yield a wide-screen 16:9 aspect ratio) is time-compressed by a factor of 4 and added to the NTSC signal in the left and right overscan edges of the image area. The chroma components of this signal are filtered spatially and temporally to provide gaps in the signal spectrum into which other information will be inserted. It is this Component 1 signal that NTSC receivers will decode, with the side-panel information in the overscan areas where it will not be noticed.

The remaining side panel information from left and right side panels is concatenated, with the boundary between the two parts controlled using a tapered smoothing operation. Next, a random point in the concatenated side panel data is used as a starting point for a cyclical reorganization of the side panel data. This has the effect of randomizing the horizontal location of this side panel information before Component 2 modulation. After this side panel information is time-expanded (expansion factor = 3.75 = 15/4), a Fukinuki carrier at 3.579545 MHz is modulated with side-panel Q (chrominance) and side-panel high-frequency luminance on one phase of the carrier. The wideband I (in-phase chrominance) component for side panels and a side panel luminance difference signal representing the side panel luminance information between 1 MHz and 2 MHz are modulated on the quadrature phase of the same Fukinuki carrier, to produce Component 2. This Fukinuki carrier, unlike the color sub-carrier at the same frequency, switches phase on every field. Prefiltering is provided to minimize interference with Component 1 and insure separability of components at the receiver. The scrambling just described is intended to reduce visibility of this information at the receiver, where it occupies the same spatial territory as the center panel (NTSC) area of the picture.

Component 3 is formed from luminance signals only that span the entire width of the wide screen format and have frequencies in the range 4.5 to 6.6 MHz. These are vertically low-pass filtered, and frequency-shifted downward by 3.58 MHz. This is followed by a time expansion of one line in four by a factor of 4 to compress the spectrum of this component to the region 230 kHz to 750 kHz. The resulting signal is modulated (as Component 3) in quadrature on the main RF carrier.

The ACTV system has a potential capability for a pan-and-scan feature that allows for displacement of the center panel within the wide-screen image. (It is the understanding of the Task Force that the pan-and-scan feature will not be included in the ACTV system to be tested.) The pan-and-scan capability would be accomplished by reassigning, during a raster mapping operation, the contents of the information transmitted in side-panels. For an off-center displacement of the center panel, the widths of the transmitted side panels remain equal, but the diminished side panel's information will be augmented with the additional image data for the augmented side panel.

The ACTV receiver includes ghost canceling that uses a training waveform transmitted on a single line in the vertical interval. After analysis of the received training signal and optimization of filter coefficients, a combination of an FIR filter for short-delay ghosts and an IIR filter for long-delay ghosts cancels the ghosts. The range of cancellation is roughly 2 microseconds pre-ghost to 30 microseconds post-ghost.

At an ACTV receiver, Component 3 is retrieved by quadrature detection applied to the RF carrier, and the wideband components are reconstituted by time compression, frequency translation, and vertical low pass filtering.

At an ACTV receiver, Component 2, containing side panel information, is obtained by intraframe differencing of the high frequency signal demodulated from the in-phase component of the carrier. Demodulation using the quadrature-phase carrier yields the side panel I component and the side-panel luminance difference signal, and a Nyquist filter and demodulation with the in-phase carrier yields the Q components. Raster mapping with a compression factor of 3.75 corrects the time scale, and band-splitting filtering and noise reducing circuits are used to produce the side panel luminance high frequency component and the side panel I and Q chrominance components.

For Component 1, an ACTV receiver applies noise reducing techniques to the side panel information contained in the overscan regions at left and right. A raster mapping operation expands the side panel luminance low frequency information and provides smooth transitions between center and side panel image data. The low frequency center panel information is time compressed by a factor of 1.25 to become the low-frequency luminance information for the center panel. The high-frequency center panel information is intraframe averaged, yielding an NTSC-like signal for the center panel. The I and Q components are decoded using the in-phase and quadrature 3.579545 MHz sub-carrier, and the luminance and chrominance components are time-compressed by 1.25 to correct the time scale.

Side panel information and center panel information are spliced together with smoothing at the boundaries that uses a gradually weighted transition between regions of overlap. The entire wide screen signal is converted to progressive scanning for display, using vertical line averaging for chrominance. The luminance conversion uses a motion-adaptive algorithm that gradually switches between a vertical (fast motion) and temporal (slow motion) averaging, as a function of motion in the images.

An NTSC receiver is expected to largely reject Component 3 in most cases. The signals making up Component 2, on two phases of the Fukinuki carrier, will presumably be masked in an NTSC receiver by virtue of their small relative amplitude and the effect of the observer integrating the complementary colors produced by the interference on alternate fields. The side panel information of Component 1 will normally be invisible in the overscan regions of NTSC receivers.

The audio information for ACTV is transmitted both as an analog FM modulation using a BTSC stereo sound channel at 4.5 MHz offset from the visual carrier (that will be received by NTSC receivers), and using compressed digital audio with a digital audio carrier at 1.1 MHz below the visual carrier. The digital channel, used for audio and potentially available for auxiliary data, employs QPSK modulation to produce a data rate of 354.6 k-bits per second, with 341.3 k-bits per second devoted to compressed audio and error correction, leaving potentially 13.3 k-bits per second for auxiliary data. (The system to be tested will not have auxiliary data interfaces.)

In producing all of the component signals, the ACTV system takes care to prefilter the component and sub-component signals so as to prevent interference at later stages. At the receiver, similar filtering is used to keep components separate. These are essentially analog filtering operations (albeit probably with digital implementations), and compromises and trade-offs have necessarily involved discarding some picture information and allowing inseparable interferences. Therefore, both objective and especially subjective tests will need to evaluate the effects of the compromises and trade-offs.

## III. SUMMARY OF POTENTIAL IMPAIRMENTS

The technical analysis has aimed at identifying areas of technical concern, and at suggesting ways of examining those areas. The Task Force has focused on areas that we believe may not be tested in the current SS-WP2 testing procedure, but we also list, for completeness, items of concern that may be addressed by existing tests. The list of items may be most usefully thought of as providing guidelines to expert viewers in the testing process, who will be alerted to potential problems. The technical nature of the items will make it less useful to address these concerns in the subjective phase of testing. Although some items may lead to recommendations for system-specific tests, practical limits on testing resources may delay such tests to the Field Test phase.

The ACTV system includes a number of distinct component signals in addition to the NTSC components. It is known from experience that NTSC can suffer from minor transmission impairments that cause interference among components. Very much of the processing in ACTV involves fundamentally analog multiplexing implemented through digital processing. The purpose of the multiplexing is to keep the components from interfering with one another, and the trade-offs and compromises involved in such a system inevitably lead to video and audio impairments. One of the things that needs to be tested is whether the larger number of components in the ACTV system can be made robust with respect to channel impairments and the existence of particular video signals in the images. It could be that there will be less tolerance for channel perturbations and image peculiarities than in NTSC.

The items for examination have been categorized under headings for ideal and non-ideal conditions:

**A. IMPAIRMENTS UNDER IDEAL CONDITIONS**

Among the areas of concern for the ACTV system, when the encoding for transmission and the decoding at the receiver are exactly as described by the proponent, and the transmission channel has no significant impairments, are potential impairments under such ideal conditions.

a. Visibility of side-panel stitching.

   The description of raster mapping and splicing seems to provide for a very smooth transition between regions, but since this is a constant feature of the wide-screen display, and the virtual boundary between side and center panels is vertically correlated from top to bottom, the visibility of the splicing needs to be observed with smooth image fields that will not mask any boundary artifacts.

b. Pan-and-scan operation [if it were part of the system].

   The smoothness of panning and the visibility of a moving vertical boundary between center and side panels need to be evaluated. The secondary splicing or stitching together of the two parts of the augmented side panel should also be examined, since these two parts are transmitted separately.

c. Motion artifacts.

   The main motion effects are expected to be smearing of moving edges, due to operation of noise-reducing circuits and a motion adaptive scan conversion for luminance. The motion adaptive progressive scan conversion may also introduce various temporal artifacts, such as breaking up of edges and an unnatural flicker. The effects in the center panel may be different from that in side panels.

d. Visible artifacts from non-perfect separation and combining of multiplexed components.

   These artifacts could take many forms, depending on the components and the image content. Among the concerns are low-frequency luminance resulting from spillover of Component 3 into the main signal. This could occur for high frequency (e.g., 6 MHz) vertical grating signals with high contrast. Small area signals may exhibit a 30 Hz flicker, and this effect should be explored.

e. Visibility of side-panel information in the center panel.

   Although we do not know the level of Fukinuki carrier, the side-panel luminance high frequency components and chrominance components occupy the same spatial territory as the center panel (and NTSC) video signal. Moving high-contrast edges in side panels may be visible in smooth still center panel regions.

f. Maximum-envelope signals.

   An attempt should be made to identify a signal or signals that yield peak excursions of modulation of the various carriers and sub-carriers, not with the idea of "breaking" the system, but to examine, for calibration purposes, the behavior of the system at the boundary of its performance. The system description did not have enough information on subcarrier levels to develop such a set of signals.

**B. IMPAIRMENTS UNDER NON-IDEAL CONDITIONS**

Under non-ideal conditions, the following are some potential sources of impairments:

*1. With Channel Impairments*

Because the ACTV system is uniquely (among the proposed systems) a compatible extension of NTSC, the system needs to be evaluated with impairments that historically have been a problem for NTSC. While the objective tests planned for the first phase of tests may not exhaustively explore such impairments, we list areas of concern for possible consideration in field tests, if not in the laboratory tests. The envelope of practical tolerances for channel parameters such as carrier-to-noise ratio, frequency response variation, differential gain, differential phase, group delay and ICPM (incidental carrier phase modulation) needs to be explored before final acceptance of a system like ACTV.

a. Visibly different noise field in side panels compared to center panel:

   The ACTV design explicitly includes an effort to match the noise characteristics between side panels and the center panel. However, since the processing of side panel information is in many ways different from center panel information, the success of this matching should be verified.

b. Visibility of side-panel stitching.

   As for the ideal case, the visibility of the vertically oriented boundary between center and side panels needs to be examined, under impaired channel conditions. If the pan-and-scan feature were to be incorporated, the display should also be scrutinized to see if the vertically oriented secondary boundary for an offset center panel can be observed.

c. Low-frequency interference resulting from quadrature crosstalk from Component 3.

   The concern is that multipath-induced phase shifts could cause crosstalk of the RF quadrature component into the main signal, where it may result in low-frequency luminance patterns.

d. Crosstalk from main signal into Component 3.

Inadequate separation of the components could lead to main signal elements causing high frequency interference through Component 3. Such interference would be correlated in a peculiar way, because of the 4:1 time compression of the received signals and the vertical filtering.

e. Loss of high frequency horizontal details in presence of noise or interference conditions.

The high frequency information in Component 3 may be lost in noise or interference conditions, since the Component 3 level should be kept low to avoid interference.

f. Loss of side panel color or of side panel luminance details in presence of noise or interference conditions.

The Component 2 power level will be low to avoid interference, making it vulnerable to noise.

g. Loss of digital audio in noise, multipath or other interference conditions.

The robustness of the aural channel has been a strength of NTSC, allowing viewers to continue attention to program material even when the visual signal is impaired or lost. Since digital channels generally have a less graceful degradation characteristic, the way in which the aural channel fails and the threshold at which it fails are important.

h. Perceptually noticeable vertical orientation of high frequency random noise field.

This could result from the vertical filtering over 4 lines of high frequency luminance details.

*2. Imperfect Receiver*

The principal receiver imperfections we consider for ACTV are those of the NTSC receivers that must compatibly receive the ACTV signal. These effects are discussed briefly below under NTSC Compatibility.

*3. Channel Impairments and Imperfect Receiver*

Again, ACTV compatibility with NTSC receivers is the issue.

## IV. COMPATIBILITY WITH NTSC

The addition of signal components beyond those in an NTSC signal may lead to interference to adjacent channels, to a signal occupying the same channel at a different location, and uniquely in the case of NTSC, to NTSC receivers that must compatibly receive the ACTV signal.

### A. PERFORMANCE OF ACTV WHEN VIEWED ON NTSC RECEIVERS

Since a main advantage claimed for ACTV is its compatibility with NTSC receivers, the performance of a representative sample of NTSC receivers when presented with an ACTV signal is important. The scope of objective testing planned by Working Party 2 of the effect of NTSC receivers with an ACTV signal input appears to be ambiguous. Since a sample of NTSC receivers is available at the testing laboratory, those receivers could be used for objective as well as subjective testing of ACTV into NTSC receivers by expert observers. The restriction to only expert observers is appropriate for the observations we suggest because effects may be subtle, and because the NTSC receivers are necessarily a limited and not completely representative sample of the universe of current and future NTSC receivers, including improved definition NTSC receivers.

Among the items to be objectively assessed using representative NTSC receivers are:

a. Visibility of side panel information in receivers with inadequate overscan.

b. Visibility of side panel information in receivers in case of multipath of various delay and amplitude.

c. Visibility of a low frequency luminance pattern due to Component 3 (high frequency luminance information translated and compressed in frequency and modulated in RF quadrature).

   This could result from envelope detectors (or quasi-synchronous detectors in multipath conditions) in NTSC receivers failing to reject the RF quadrature component, when there is large amplitude high frequency luminance information in the ACTV signal. This may produce small-area flicker.

d. Visibility of dot patterns due to the added Fukinuki carrier.

   As the amplitude of the Fukinuki carrier is unknown, it is difficult to predict the severity of this effect, but NTSC receivers that were not designed to carefully separate alternate carrier signals may not adequately reject the Fukinuki components.

e. Interference in the sound channel for NTSC receivers.

   This may result from Component 3 generating phase modulation of the picture carrier. In envelope detectors or quasi-synchronous detectors, the resultant phase modulation of the main visual carrier could be detected as frequency modulation in the BTSC stereo sound signal.

**B. INTERFERENCE OF SUBJECT SYSTEM WITH NTSC BROADCASTS**

*1. Interference from ACTV into NTSC*

a. Interference at specified tolerance for undesired ACTV signal.

   The question is whether ACTV signals create more interference in NTSC receivers, when they are the undesired signals, than do NTSC signals.

*2. Interference from NTSC into ACTV*

a. Interference at specified tolerance for undesired NTSC signal.

   The question is whether ACTV receivers are more vulnerable to undesired NTSC interfering signals than are NTSC receivers.

b. Interference from lower adjacent sound channel into ACTV digital carrier.

The digital aural carrier for sound is at 1.1 MHz below visual carrier, so that, in the absence of offsets, the lower adjacent sound carrier is only 0.4 MHz from the digital carrier. The digital sound carrier is sent at 30 dB below visual carrier level, and may be vulnerable to a relatively strong lower adjacent sound channel. The undesired station can be much closer to the receiver than the desired station with digital carrier, and frequency offsets can reduce the frequency spacing.

### C. COMMENTS ON DOWN-CONVERSION TO NTSC FOR RE-BROADCAST

It appears that down-conversion for ACTV would be a direct demodulation by a carefully adjusted NTSC demodulator or an ACTV demodulator designed to deliver only the NTSC components. Such a down-conversion could benefit from the pre-filtering in ACTV that should suppress aliasing components in the NTSC signal.

## V. RECOMMENDATIONS FOR SYSTEM-SPECIFIC TESTS AND OBSERVATIONS

As indicated earlier, the tests recommended reflect the views of the Analysis Task Force concerning technical issues that we believe need to be examined. They may be interpreted as guidelines to alert expert viewers to potential problems, or they may be formalized as part of the system-specific objective tests.

In addition to recommending scrutiny by expert observers to report on effects described above in the section on potential impairments, we list below some specific tests and observations that will illuminate some of the technical issues.

a. Co-channel interference test:

   At the precise offset specified by Sarnoff, set the desired NTSC received signal to -35 dBm and an undesired NTSC receiver input signal at -63 dBm (D/U ratio of 28 dB). Substitute an undesired ACTV input signal of -63 dBm for the NTSC signal and repeat the observation and recording. Interchange the NTSC and ACTV roles making the ACTV the desired signal and display on an ACTV receiver. Observe and record the results. Repeat for ACTV to ACTV. Change the offset by 30 Hz and repeat the foregoing.

b. Adjacent channel interference test.

   The upper channel frequency should be shifted 10 kHz downward from nominal, and the lower channel frequency should be shifted upward by 10 kHz, to minimize inter-channel frequency spacing. The digital aural channel level should be set to a level specified by Sarnoff. When NTSC is the desired signal, the aural carrier is to be at a level of 10 percent of peak visual power level. When the NTSC signal is undesired, the aural carrier is is to be 20 percent below peak visual power level. The desired signal in each case should be at -55 dBm level. The undesired signal should be adjusted over a range of values including levels of -15 dBm, -35 dBm, and -55 dBm. NTSC interference and ACTV interference should be compared as in the co-channel case. A particular concern is the case where the undesired aural signal in the lower adjacent channel interferes with the digital aural signal in the desired channel.

c. Scrutinize the display to observe indications of the boundary between center and side panels. This should be done with no impairments and with practical levels of channel impairments.

d. Scrutinize the display in the presence of noise to observe the character of noise "snow". Report on any unusual characteristics or shape of the "snow" particles.

e. Scrutinize the left and right edges of the display of NTSC receivers for side panel information that is visible in the overscan regions. This test needs to be done for the collection of representative NTSC receivers.

f. Scrutinize the center panel to observe visibility of Fukinuki components from side panels, when the central image is non-moving and smooth and side panels have sharp moving edges.

g. High-frequency luminance crosstalk.

   A signal representing roughly 6 MHz high contrast luminance, such as a vertical grating signal, should be used to exercise Component 3. The displayed picture should be scrutinized by experts for crosstalk effects described under impairments above. The test should be conducted both with and without multipath and phase noise typical in set-top converters.

h. Color smear on sharp horizontal edges.

   Observe and report on color smearing when the image has sharp horizontal or nearly horizontal edges.

i. Scrutinize the displayed picture on an NTSC receiver for 30 Hz luminance flicker, with high levels of luminance content in the enhanced resolution passband. This might best be observed using a test signal that produces small areas with high resolution (wideband component) imbedded in a flat field. (See the next item for a related signal.)

j. It has been suggested that at some point in the testing and evaluation process, a special test signal could be used to explore the effects of possible crosstalk from Component 3 into the main signal components, and especially into visible artifacts in NTSC receivers.

   An example of the kind of test signal that would exercise Component 3 is one that has a periodic bar repeating 4 times across the width of the wide screen, so that the time-expanded lines in Component 3 have one instance of the bar in each expanded line, with the time-expanded bars aligned (by adjusting the spacing in the original). The bar should contain approximately 6 MHz high contrast luminance information. If ACTV transmissions are to beneficially include such high frequencies, it will be interesting to see the extent of interference such signals may cause in ordinary NTSC receivers that ideally will not respond to such a signal. The test should be conducted both with and without multipath and phase noise typical in set-top converters.

## VI. CONCLUSIONS

The Analysis Task Force of the Systems Subcommittee's Working Party 1 has studied the descriptive material supplied for the ACTV system, and our analysis indicates the system will operate essentially in the manner described. The Task Force has identified areas of concern regarding certain technical issues, and these have been addressed in a list of questions supplied to the David Sarnoff Research Center, and in a section detailing potential impairments under ideal and non-ideal conditions. There is also a section containing recommendations for system-specific tests. Appendix C contains a list of desired clarifications to the system documentation, as well as additional recommendations for system specific tests beyond those contained in the Draft report.

Among the concerns not addressed in this report is the potential for interference between ACTV signals and future simulcast ATV transmissions that may alter the historical rules governing spectrum usage and transmitter spacing.

The Task Force has also not addressed the potential for improvement in images received by NTSC receivers with an ACTV input signal. Such improvements can result from the care taken to separate the different signal components, leading to a possible reduction in common NTSC aliasing artifacts like cross-color and cross-luminance.

Besides the possibility of influencing the choice of system-specific tests in the objective testing phase planned by Working Party 2, another area in which the observation of potential impairments can be useful is in identifying image artifacts that could be too subtle to show up in short-term subjective tests using non-technical observers. In other words, short-term subjective tests may not allow enough time to indicate a significant problem, even though the image artifact could prove annoying to the average viewer when observed routinely over a long period of time (such as the lifetime of a TV receiver, or of a TV standard).

# APPENDIX A

## QUESTIONS TO PROPONENT

## FROM ANALYSIS TASK FORCE

**Questions Concerning ACTV System from SS/WP1-X**

1. What is the precise frequency (to 1 Hz) to which the main carrier should be set (for co-channel interference test, i.e., ACTV into NTSC and NTSC into ACTV)?
2. What is the precise frequency difference (to 1 Hz) at which tests for co-channel interference would be run for minimum interference?
3. Is there a different frequency offset that would result in significantly greater co-channel interference?
4. What is the level of the digital audio carrier (at 1.10 MHz below visual carrier)?
5. What is the level of the Fukinuki carrier for Component 2?
6. What are the bandwidths, with 3 dB and 20 dB points, for signal processing filters?
7. Specify the precise clock frequencies for digital filtering and processing of video, audio and data information (needed for interference considerations by the testing lab).
8. Provide clarification of noise compression algorithms, including time constants and equivalent S/N gain for given carrier level.
9. What value of "leak" is used in the DPCM-Type noise reduction processing?
10. Describe the ghost canceling method that will be used in the system submitted for test, including range of delay and ghost levels and number of discrete ghosts that are correctable. Describe training signal and vertical interval usage.
11. What attenuation, if any, is applied to the high frequency components of Component 3, before spectral compression?
12. What is the visual effect of a "low-level interference pattern" that may be produced by Component 3 when an NTSC receiver uses envelope detection?
13. Specify the gain and attenuation factors applied to each signal component in processing, for encoding and decoding.
14. Provide a worst-case modulation diagram, showing the encoded modulation as a function of time, with peak limits.
15. Does the audio in the ACTV receiver to be submitted for testing switch to intercarrier sound for low S/N conditions? If so, at what point in S/N does the audio in the ACTV receiver switch, and is there an indication in the ACTV receiver submitted for test when such a switching action takes place?
16. Does the ACTV receiver submitted for testing switch to NTSC-only mode as a function of (low) S/N? (and if so, at what point?)
17. What is the precise total bit rate of the digital channel, including audio, auxiliary data, and overhead bits? Will the auxiliary data channel be loaded with random data, and is scrambling employed in the digital channel to minimize spectral interference?

18. Clarify the delay tolerance between the audio and visual signals for an ACTV transmission received by an NTSC receiver and by an ACTV receiver?

19. Specify the maximum speed of panning in the pan-and-scan capability, and the minimum horizontal displacement (i.e., panning step size) for such panning.

20. Clarify the vertical pre-filtering for Component 3. In particular, does the vertical filtering use a sliding window, or does the filtering window step down by 4 lines? Is the same line number chosen for time expansion in every field?

21. Describe the preferred method of down-converting ACTV to NTSC for the purpose of subsequent transmission as NTSC.

22. How many audio channels are provided in ACTV, and what is the bandwidth and dynamic range for each?

23. If there is a separate interface for auxiliary digital data, what is the data rate and what are the interface specifications?

24. What are the intermediate frequency and local oscillator (IF and LO) frequencies for the ACTV demodulation?

25. If double conversion is used in demodulation, provide data on both conversions, including the bandwidths at both intermediate frequencies.

26. Describe in technical detail the automatic gain control (AGC) reference provided for ACTV. Describe the relevant range of signals for which the AGC system should operate.

27. Describe the matrix equations for converting the R, G, and B signals at the encoder input to luminance and chrominance components, and for converting back to R, G, and B outputs at the decoder. If the equations are those specified by the FCC for NTSC, or are as defined in SMPTE 240M, this should be noted. If temporal and spatial responses of the color difference signals are not the same as specified by the FCC for NTSC or as defined by SMPTE 240M, then the color difference signals should be specified separately.

28. Is there a signal analogous to NTSC color burst that indicates an ACTV transmission is being received? If so, what is the nature of the identifying signal?

Among the third category of more general information requests are the following:

A. Describe any anticipated impact on the testing program that may result from changes made to ACTV since ACTV-I received preliminary certification.

B. Identify any problems you envision in adequately testing the ACTV system using the testing procedures adopted by SS/WP-2. Include recommendations for changes in the test procedures that will ameliorate such problems.

C. Identify system features claimed for ACTV that will not be included in the system submitted for test.

D. Estimate the potential for interference into both NTSC and ACTV of subcarriers used in the ACTV system.

E. Provide a unified document describing the system submitted for test, so that references to outdated or incomplete other documentation can be avoided. This documentation should be available before actual testing begins.

# APPENDIX B

## RESPONSE TO

## TASK FORCE QUESTIONS

## FROM SYSTEM PROPONENT

# Questions Concerning ACTV System from SS/WP1-X

1. What is the precise frequency ( to 1 Hz) to which the main carrier should be set (for co-channel interference test. i.e., ACTV into NTSC and NTSC into ACTV)?

   Depends on the channel being tuned. Otherwise see Question 2.

2. What is the precise frequency difference (to 1 Hz) at which tests for co-channel interference would be run for minimum interference?

   10010 Hz

3. Is there a different frequency offset that would result in significantly greater co-channel interference?

   ACTV behaves like NTSC with regard to co-channel interference.

4. What is the level of the digital audio carrier (at 1.10 MHz below visual carrier)?

   30 dB below picture carrier

5. What is the level of the Fukinuki carrier for Component 2?

   The level of the modulation on the Fukinuki subcarrier and its relation to noise reduction parameters is still under study with a variety of source material. The accompanying Figures 1 and 2 give insertion gains of the various signals in the ACTV system. The signals on the Fukinuki subcarrier are shown in parallel paths in the lower portions of the picture, identified as "yqs" (for luma and chroma Q component for the side panels) and "is" (for chroma I component for the side panels). The linear gain factors are shown in the lower left corner of the figures, identified as Q-component side panel gain (QSG), combined side luma and side Q gain (YQSG), I-component side gain (ISG), and an overall encoder gain (EG). These signals on the subcarrier are non-linearly companded both statically and dynamically. In addition, there may be receiver-only processing further to aid recovery in noisy conditions.

6. What are the bandwidths, with 3 dB and 20 dB points, for signal processing filters?

   The Figures 1 and 2 also show the various system filters. The function of each filter is described in words below. Figures 3 and 4 shows the general format for specifying passband, stopband, transition band, and cut-off frequency; the specifications for each filter are in the accompanying Table 1.

**Encoder Filters**

HZF #E1 Initial bandlimiting filter for center panel I (IC).

HZF #E2 Initial bandlimiting filter for center panel Q (QC).

HZF #E3 Bandsplit filter for center panel Y lows (YCL). This filter determines how much center panel luma will contain full V-T resolution. For a flat center panel luma response, this filter should be the complement of HZF #E5.

HZF #E4 Bandsplit filter for side panel Y lows (YSL). It determines how much side panel luma will contain full V-T resolution. Its cut-off frequency must be low enough so that the signal, after time compression, will pass undistorted through the channel filter. For a flat side panel luma response, the convolution of HZF #E4 and HZF #D9 should be the complement of the convolution of HZF #E7 and HZF #D10.

HZF #E5 Bandsplit filter for center panel Y highs (YCH). This filter determines how much center panel luma will contain half V-T resolution (be intraframe averaged). For a flat center panel luma response, this filter should be the complement of HZF #E3.

HZF #E6 Bandlimiting filter for side panel luma, without YHH (Component 3). For spectrum efficiency, this filter should be sharp. Any ringing will be canceled when YHH is added back in. Bandlimiting for center panel luma is performed by the channel, which is a very sharp filter. This gives the compatible set a sharp main picture. To yield a flat side panel response, this filter should be the complement of HZF #E10.

HZF #E7 Bandsplit filter for side panel Y highs (YSH). It determines how much side panel luma will be intraframe averaged, and it also affects crosstalk between YSH and QS.

HZF #E8 Initial bandlimiting filter for side panel Q (QS). It affects crosstalk between QS and YSH.

HZF #E9 Initial bandlimiting filter for side panel I (IS).

HZF #E10 Bandsplit filter for widescreen Y high-highs (YHH, or Component 3). This filter determines the lower end of the YHH band; HZF #E14 determines the upper end.

HZF #E11 This filter determines the lower limit of the band of luma frequencies prefiltered by Qbert.

HZF #E12 — This filter suppresses any harmonics and repeat spectra that may be present after noise reduction and time expansion of the combined YSH/QS signal (YQS). It prevents crosstalk from modulated YQS into center panel luma.

HZF #E13 — Inverse Nyquist-slope filter for modulated IS. The gain of this filter should be exactly 0.5 at 3.58 MHz

HZF #E14 — This filter determines the upper band edge for YHH. The nominal upper cutoff frequency for YHH is 3.58 MHz higher than the cutoff frequency of this filter.

HZF #E15 — This filter suppresses any repeat spectra that may be present after time expansion of YHH. It limits crosstalk from YHH into the ACTV signal.

## Decoder Filters

HZF #D1 — Highpass filter for modulated Component 2 plus center panel of Component 1. The complement is generated by a subtracter module. It determines the range of center panel luma frequencies that will be intraframe averaged.

HZF #D2 — This filter determines the lower limit of the band of luma and modulated chroma frequencies processed by Qbert decoding.

HZF #D3 — Demodulation filter for recovered IC (before raster mapping).

HZF #D4 — Demodulation filter for recovered QC (before raster mapping).

HZF #D5 — Bandshaping filter for center panel luma. This filter yields the complementary slope for YHH to yield a flat response.

HZF #D6 — Nyquist-slope filter for modulated YQS. The convolution of this filter with HZF #E13 should be exactly double sideband around 3.58 MHz. The gain of this filter should be exactly 0.5 at 3.58 MHz

HZF #D7 — Demodulation filter for recovered YQS (before raster mapping).

HZF #D8 — Demodulation filter for recovered IS (before raster mapping). To prevent quadrature crosstalk from YQS, the cutoff frequency of this filter must not be larger than about 1 MHz.

HZF #D9 — Final bandshaping filter for YSL.

HZF #D10 — Bandshaping and separation filter for YSH. It affects flatness of side panel luma response and crosstalk from QS into YSH.

HZF #D11 — Separation filter for QS. It affects crosstalk from YSH into QS.

HZF #D12 — Final bandlimit filter for I. Tends to smooth out any seam artifacts.

HZF #D13 — Final bandlimit filter for Q. Tends to smooth out any seam artifacts.

HZF #D14 Lower sideband reject for YHH. Should be flat above 4 MHz to insure correct bandshape for frequency seaming.

7. Specify the precise clock frequencies for digital filtering and processing of video, audio, and data information (needed for interference considerations by the testing lab).

Video sampling is done at 57.27272 MHz in the encoder. All other processing is done at either 28.63636 MHz or at 14.31818 MHz. All frequencies are scaled down from a clock at 114.54544 MHz. In the decoder, the clock generates a master frequency of 57.27272 MHz and divides this down to 28.63636 MHz or 14.31818 MHz.

Audio is sampled at 48 KHz.

8. Provide clarification of noise compression algorithms, including time constants and equivalent S/N gain for given carrier level.

The System Description of 12/31/89 included both PCM-based and DPCM-based noise reduction techniques applied to the side panel signals. It indicated that DPCM would be used for luma side panel high frequencies (YSH), which have no DC component. PCM-based noise reduction would be applied to the rest of the side panel signals - luma low frequencies and both I and Q components of side panel chroma (IS and QS). Experiments and optimization since 12/31/89 have allowed simplification of the ACTV system so that the same noise reduction approach (PCM) is now applied to both signals that share the same phase of the alternate subcarrier (YSH and QS). These experiments also indicate that, as optimization of the noise reduction parameters continues with a variety of source material, PCM-based noise reduction will be applied to all the side panel signals.

ACTV's noise reduction is accomplished by companding, which is a non-linear process. Companding can either improve or degrade the S/N of the recovered signal; to be effective, the signal amplitude must, with high probability, be in the noise reduction portion of the curve. ACTV tailors the compandor to the recovered signal by using motion-adaptive prediction at both the encoder and decoder to select among different companding curves.

Figure 5 shows how both low-level and high-level signals are noise-reduced by placing maximum compandor gain at the predicted signal level. Encoder and decoder curves are complimentary. An example family of companding curves is shown in Figure 6. A schematic of the complete system is shown in Figure 7. The indicated noise is that which is added in the transmission path. Note that the encoder includes a copy of a typical decoder circuit so that distortions introduced, for example, by channel filters, are compensated before transmission.

The slope of the companding curve is described by its "mu-law." Figure 8 shows an expander function which is a mu-law of 30. Typical probability density functions (PDF's) for input and output noise are shown. The sigma of the output noise can be expressed:

$$\text{SIGMA\_OUT} = [\Sigma_x \text{ PDF\_IN}(x) \text{ EXPANDER}^2(x)\ \Delta x]^{0.5},$$

where SIGMA_OUT is the RMS output noise and $\Delta x$ is the step size used in the summation. This SIGMA_OUT can be compared with SIGMA_IN to determine the amount of noise reduction provided by the expander.

Figure 9 shows the resultant noise reduction of mu-law companders for subchannel SNR from 0 dB to 50 dB; the subchannel SNR is defined as maximum peak-to-peak signal/RMS noise--standard video SNR definition. It must be stressed that the subchannel SNR is the SNR with which the noise reduction circuit is operating-- it may be lower than the main channel ("NTSC") SNR-- particulary when signals are attenuated. Figure 9 shows that the amount of noise improvement, in general, goes down at low SNR. This is because the input signal falls outside of the maximum noise gain region more and more with increasing noise. At extremely low SNR, the amount of noise improvement rises again. This is because the noise gets clipped by the expander function (notice in Figure 8 how inputs having absolute value greater than 0.5 are clipped at the output to -0.5 or +0.5).

We operate the ACTV subchannels at an input S/N that requires an approximately 10 dB improvement from noise reduction.

This diagram allows predictions about noise reduction requirements. In the absence of noise reduction, the difference between the channel SNR and any subchannel SNR is a fixed amount [dB]. Noise <u>densities</u> have been calculated for the various subchannels, in order to determine noise reduction requirements. The relation between the channel and subchannel SNR is determined by integrating their noise power density functions. The relevant noise density functions are those that appear at the input to the noise reduction decoder circuits.

9. What value of "leak" is used in the DPCM-Type noise reduction process?

We have simplified the system to a single type of noise reduction; PCM noise reduction is now employed universally, and it has no "leak."

10. Describe the ghost canceling method that will be used in the system submitted for test, including range of delay and ghost levels and number of discrete ghosts that are correctable. Describe training signal and vertical interval usage.

The ghost cancelling system uses a combination of an FIR filter (for close ghosts) and an IIR filter (for long ghosts). The analysis of the training signal and optimization of the filter coefficients is done in software written, for these tests, in a high-level language. The particular IIR filter we will deliver for test will cancel 5 discrete "long" ghosts. The absolute maximum ghost levels have not been determined, but we routinely test with single ghosts 6 dB below the desired signal. The system with its present software will not cancel multiple ghosts if each of their amplitudes is as large as this. The delay range is from about a 2 microsecond pre-ghost to about a 30 microsecond post-ghost. However, I note that the particular parameters of the ghost canceller we deliver for test are essentially unrelated to the ACTV system itself. ACTV recovery is not dependent on ghost cancelling to avoid catastrophic failure - ghost cancelling merely improves the picture, as it does for NTSC.

The training signal is a pseudo-random sequence that requires one line of the VBI. The ACTV timing reference uses this same sequence.

11. What attenuation, if any, is applied to the high frequency components of Component 3, before spectral compression?

Component 3 contains horizontal luminance high frequencies. They are sent at 6 dB below their natural level, which itself is usually low for normal video.

12. What is the visual effort of a "low-level interference pattern" that may be produced by Component 3, before spectral compression?

Tests on our bank of receivers indicate that some designs may show a faint moving pattern, depending on the energy in Component 3; the pattern can usually only be seen against a plain gray background.

13. Specify the gain and attenuation factors applied to each signal component in processing, for encoding and decoding.

These gain and attenuation factors are given in Figures 1 and 2, previously referenced.

14. Provide a worst-case modulation diagram, showing the encoded modulation as a function of time, with peak limits.

ACTV's modulation is like NTSC, with the addition of our previously described "Fukinuki" subcarrier and quadrature modulation of the picture carrier. I assume from the wording of the question that "worst-case" means highest amplitude. The peak carrier power occurs during synch, just as for NTSC. The maximum levels of video modulation will be controlled so as not to exceed those of NTSC.

In the case of ACTV, the highest carrier amplitude would be obtained by maximizing the energy on the Fukinuki subcarrier as well as the center panel and Component 3. In general, this requires high luminance detail and highly saturated chroma everywhere in the picture. Test patterns can be constructed that exceed ACTV's intended dynamic range, just as can be done for NTSC. ACTV's signal levels are set to pass realistic video comfortably. In commercial encoders, adaptive level control or adaptive soft clipping would be implemented, but this is not part of the test hardware.

15. **Does the audio in the ACTV receiver to be submitted for testing switch to intercarrier sound for low S/N conditions? If so, at what point in S/N does the audio in the ACTV receiver switch, and is there an indication in the ACTV receiver submitted for test when such a switching action takes place?**

At S/N (TASO) of 25 dB, audio will ocaasionally switch to intercarrier sound. At S/N (TASO) of 23 dB the audio is almost completely intercarrier sound. There is an indicator lamp which shows the audio status (digital or intercarrier sound), but this is not located on the front panel. It is inside a signal processing tray.

16. **Does the ACTV receiver submitted for test switch to NTSC-only mode as a function of (low) S/N? (and if so, at what point)?**

The hardware we will deliver for test does not make such a switch. It is an obvious option for receiver manufacturers, but is not a part of our system specification.

17. **What is the precise total bit rate of the digital channel, including audio, auxiliary data, and overhead bits? Will the auxiliary data channel be loaded with random data, and is scrambling employed in the digital channel to minimize spectral interference?**

The bit rate is 341.33 Kbits/sec., which includes the audio itself plus error correction overhead. There is no auxiliary data in the system delivered for test, although it is an obvious alternative use of the digital channel resource. Only analog inputs can be given at the transmitter.

18. **Clarify the delay tolerance between the audio and visual signals for an ACTV transmission received by an NTSC receiver and by an ACTV receiver.**

There is full lip synch (within a 30 millisecond tolerance) in both NTSC and ACTV receivers.

19. **Specify the maximum speed of panning in the pan-and-scan capability, and the minimum horizontal displacement (i.e., panning step size) for such panning.**

Pan and scan can be implemented in ACTV, as has been indicated in our System Description. However, as it is not part of the test plan, it will not be a feature of the hardware we deliver for test.

There is no limit to the panning speed, i.e., the image can pan from one position to any other position in one frame. With interpolation, there is no theoretical minimum step size either. A practical limit might be imposed by the finite number of control bits that would be sent.

20. **Clarify the vertical pre-filtering for Component 3. In particular, does the vertical filtering use a sliding window or does the filtering window step down by 4 lines? Is the same line number chosen for time expansion in every field?**

Component 3 is subsampled by a factor of four for transmission. Mutually exclusive groups of four raster lines are averaged within a frame, and the average replaces the original signal values. The hardware actually steps down by four lines, although, when combined with subsampling, this is equivalent to a sliding window. The same line number in every frame is chosen for time expansion.

21. Describe the preferred method of down-converting ACTV to NTSC for the purpose of subsequent transmission as NTSC.

I do not understand the question. ACTV is compatible with NTSC - there is no reason to down-convert. If there is no facility for quadrature modulation, Component 3 could be deleted.

22. How many audio channels are provided in ACTV, and what is the bandwidth and dynamic range for each?

One stereo channel (two mono) will be provided at the receiver output. In the digital mode the audio band is from 20 Hz to 20 KHz, and the dynamic range is 90 dB. In the (fall back) standard MTS analog audio mode, the audio frequency band is 30 Hz to 12 KHz, and the dynamic range is 58 dB.

23. If there is a separate interface for auxiliary digital data, what is the data rate and what are the interface specifications?

No such interface is planned.

24. What are the intermediate frequency and local oscillator (IF and LO) frequencies for the ACTV demodulation?

ACTV's IF locates the carrier at 45.75 MHz. The LO frequency depends on the channel being tuned.

25. If double conversion is used in demodulation, provide data on both conversions, including the bandwidths at both intermediate frequencies.

We will use a single conversion tuner for the testing, but single conversion or double conversion is an option for receiver manufacturers and is not part of the system specification.

26. Describe in technical detail the automatic gain control (AGC) reference provided for ACTV. Describe the relevant range of signals for which the AGC system should operate.

ACTV operates like NTSC in regard to AGC control.

27. Describe the matrix equations for converting the R, G, and B signals at the encoder input to luminance and chrominance components, and for converting back to R, G, and B outputs at the decoder. If the equations are those specified by the FCC for NTSC, or are as defined in SMPTE 240M, this should be noted. If temporal and spatial responses of the color difference signals are not the same as specified by the FCC for NTSC or as defined by SMPTE 240M, then the color difference signals should be specified separately.

ACTV's chroma is handled like NTSC's, and has similar options for receiver manufacturers to make performance/cost trade-offs that adjust chroma bandwidth.

28. Is there a signal analogous to NTSC color burst that indicates an ACTV transmission is being received? If so, what is the nature of the identifying signal?

There is no such signal in the hardware that will be submitted for test. A variety of signals for NTSC/ACTV could be defined in a future broadcast environment that includes improved NTSC, ACTV, and HDTV simulcast. Such signals include information about the channel that contains the HDTV simulcast, a ghost cancelling reference sequence, an ACTV identification if desired, and pan and scan control signals. This information, except for the ghost cancelling reference, would take less than one-half line of the VBI.

Among the third category of more general information requests are the following:

A. Describe any anticipated impact on the testing program that may result from changes made to ACTV since ACTV-I received preliminary certification.

Any changes are or will be small, with the intent of improving performance or lowering receiver cost.

B. Identify any problems you envision in adequately testing the ACTV system using the testing procedures adopted by SS/WP-2. Include recommendations for changes in the test procedures that will ameliorate such problems.

I assume that the source material will be produced without artifacts.

The spot sizes in both camera and display are designed for the highest line count systems; as such they are likely to cause more aliasing on EDTV systems than would exist with production cameras and displays. Use of a single display for all systems also prevents characterization of the beneficial effects of the higher brightness